4

MOUTH OF THE MISSISSIPPI.

JETTY SYSTEM

EXPLAINED.

BY JAMES B. EADS.

ST. LOUIS:
TIMES PRINT, N. E COR. FIFTH AND CHESTNUT STREETS.
1874.

S.W. PASS of the MISSISSIPPI.

WEST BAY

S.W. PASS LIGHT

Stake I

Pilot's Lookout

Custom House

SOUTH WEST PASS

EAST BAY

60ft 80ft 50ft 36ft 15 16ft 18ft 17ft 21ft 30ft 40ft 55ft 60ft 66ft 60ft 66ft

6ft 3ft 8ft 8ft 55ft 66ft 60ft

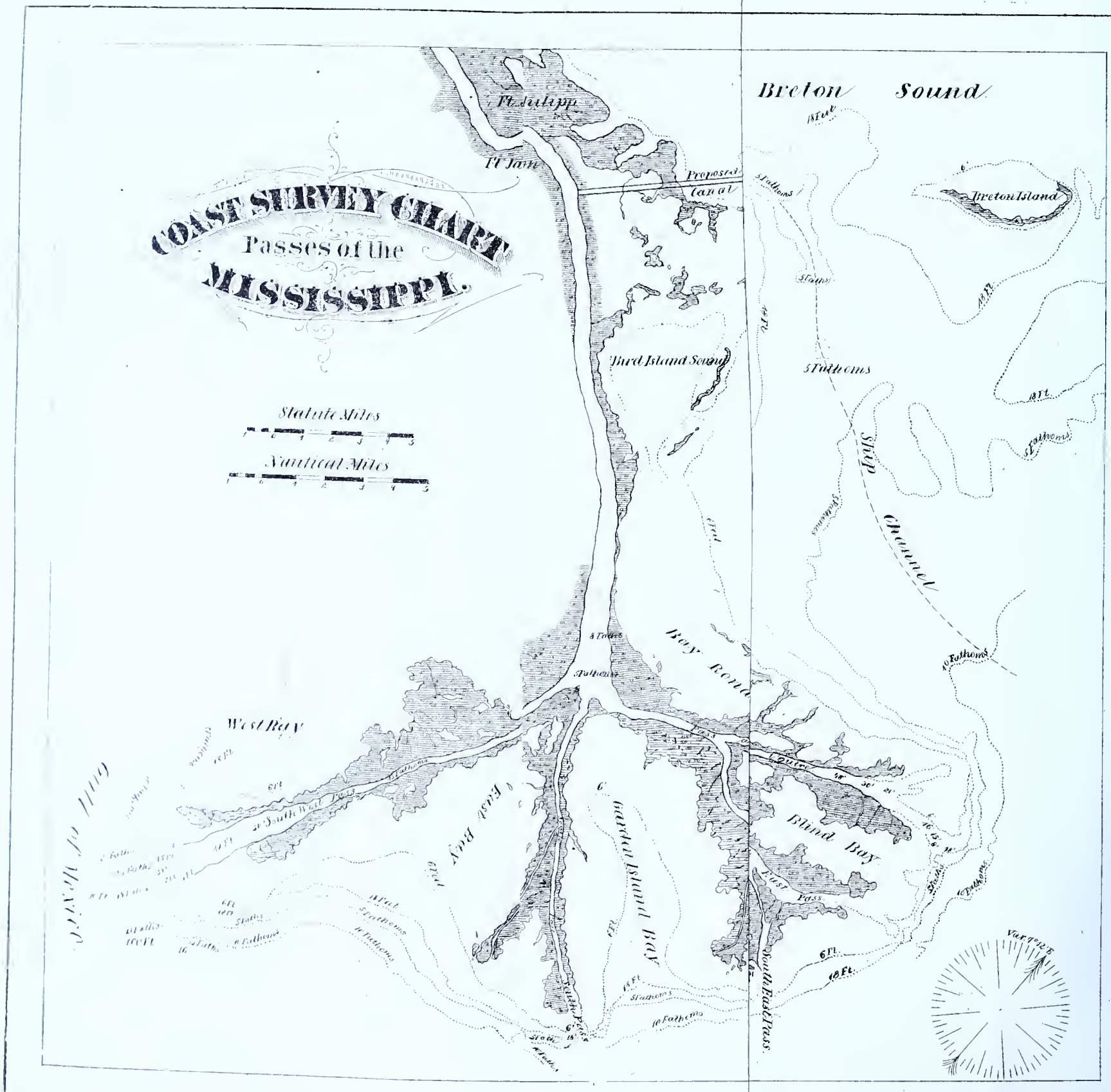
Var 2°20 E.

Nautical Miles

1 3/4 1/2 1/4 0 1 2 3 4 5

Statute Miles

1 3/4 1/2 1/4 0 1 2 3 4 5


COAST SURVEY CHART
Passes of the
MISSISSIPPI.
Ft. Jackson
Ft. Jean
Proposed Canal
Breton Sound
Breton Island
Bird Island Sound
Statute Miles
Nautical Miles
Mississippi City
West Bay
East Bay
Grand Island Bay
Bay Bonde
Pass
Blind Bay
Channel
South East Pass
Variation
5 Fathoms
10 Fathoms
18 Ft.
6 Ft.

JETTY SYSTEM EXPLAINED.

PHENOMENA OF THE MISSISSIPPI RIVER.

The Mississippi is simply a transporter of solid matter to the sea. This consists chiefly of sand and alluvion, which is held in suspension by the mechanical effect of the current. A small portion, consisting of larger aggregations, such as gravel, boulders, small lumps of clay, and drift wood, is rolled forward along the bottom. By far the greatest portion is, however, transported in suspension. The amount of this matter, and the size and weight of the particles which the stream is enabled to hold up and carry forward, depends wholly upon the rapidity of the stream, modified, however, by its depth. The banks and bottom being chiefly sand and alluvion, are easily disintegrated by the movement of the water: hence the amount of load lost by any slacking of the current at one place, will be quickly recovered in the first place below where the current is again increased.

The popular theory advanced in many standard works on hydraulics, to-wit: that the erosion of the banks and bottom of streams like the Mississippi, is due to the *friction* or *impingement* of the current against them, has served to embarrass the solution of the very simple phenomena presented in the formation of the delta of the Mississppi, because it does not explain why it is that under certain conditions of the water, it may develop with a gentle current, an abrading power, which, under other conditions, a great velocity cannot exert at all. A certain velocity gives to the stream the ability of holding in suspension a proportionate quantity of solid matter; and when it is thus charged it can sustain no more, and hence will carry off no more, and therefore cannot then wear away its bottom or banks, no matter how directly the current may impinge against them.

CAUSE OF CAVING BANKS.

In the upper portions of the delta (which, according to some writers, extends a few miles above Cairo), the width of the river is very irregular. When a rise occurs the current is increased in the narrow parts of the river, and the carrying capacity of the stream consequently becomes greater, and it at once takes up an additional load. When however, as the stream flows on, it enters a wide expanse, the current is slacked and the excess of load is dropped to the bottom, and thus shoals or bars are formed. From such expansion of channel way, the volume of water thus relieved of a portion of its load, passes into another one of the narrow parts of the channel, and here its current by contraction is again accelerated, and the increased load which it can carry is immediately scoured up from the bottom and sides of the channel. In the bends the centrifugal force of the water makes the current more rapid on the concave bank of the stream, and there it usually gets its additional load, and the caving in of the bend testifies to the rapacity of the water at that point of its course. Once loaded, however, it can carry no more, and hence it may sweep around half a score of other bends below, with equal velocity, without injury to them. If it encounter another expanse, however, it again loses part of its velocity, and with it part of its load, to be recovered again in the narrower parts of its channel below. It is evident therefore, that if the channel were at all uniform in size, the current would be more constant, and the alternate depositing and recovery of part of the burden of the stream would be prevented. This loading and unloading is synonymous with caving banks and sand bars.

The lower part of the river, nearly all the way from Red River to the mouths of the passes, is remarkably uniform in width, and is therefore comparatively free from falling banks and shoals. This part of the river is transporting its load with great regularity, and without interruption, to the sea; whilst that above, owing to the alternating contractions and expansions in its channel, transports its burden with great irregularity, dropping a part here and taking up a part there, and thus by successive stages, from season to season, it is borne forward.

If the volume of water were constant, it is plain that the river would soon have a current of great regularity; because the deposit, dropped in a wide part of the river, lessens the capacity of the

channel there by shoaling it, and re-establishes the proper velocity of current, and thus stops further deposit at that place; whilst at the contracted channel the scour soon enlarges the passage, and consequently reduces the current, and thus further scour ceases at that point.

In a channel of uniform width, when the river falls, the stream occupies only the narrower parts of it, and if these be still too great to maintain sufficient current to transport the load, the excess is deposited in the channel, which is thus further diminished until the current is thereby accelerated to the proper rapidity, after which it ceases to deposit any more.

We see, therefore, that the causes which control the speed of the stream, and those which give to it the ability to hold its burden of solid matter in suspense, are constantly acting in opposition to each other, and thus the equilibrium between them is restored as often as it is disturbed by alternations in volume, or by irregularities in channel.

We not only learn from this how simple some of the most apparently mysterious phenomena of the river really are, but also how futile it would be to attempt either to enlarge or diminish the normal size of its channel anywhere within its alluvial bed. As rapidly as the engineer strives to deepen it without proportionately contracting it, and thus enlarges it beyond the capacity which these natural forces give it, just so rapidly will the current be slacked by the enlargement and the deposit dropped there, and thus lessen it again. And as fast as he may contract it, just so fast will the current be increased, and the consequent scour enlarge it again by deepening it. The *magnitude* of the channel is determined by forces which it is neither necessary or profitable for the engineer to encounter. The *form* of the channel he can control and alter. If he widen it, these forces will inevitably shoal it; if he contract it, they will just as certainly deepen it.

FRICTION OF BED.

The chief cause which retards the flow of the stream is friction of its bed. As rivers increase in size, the volume of water increases faster than the frictional surface — as the area of a circle increases more rapidly than the circumference, when we increase its diameter. Hence, large rivers invariably flow more rapidly with the same fall than small ones. This explains why the shore current of the river is less rapid than the central current—the latter

having less friction in proportion to its volume, the gravity of water in the deep part meets with less resistance and flows faster.

HOW THE PASSES ARE FORMED.

The phenomena presented by the protusion of the passes of the river out into the Gulf, are equally as simple as those of the river above. A glance at the map shows how remarkably uniform is the width of each of them from their commencement, until they reach the neighborhood of the Gulf. In the passes and in the river, for several hundred miles above, the slower shore currents have dropped their excess of load, until the shores have been built up and narrowed in to such a degree, that all further deposits by them tend to increase the steepness of the banks; hence the additional deposit slides down towards the middle of the channel bed as fast as it is dropped. The onward motion of the stream tends to continually draw in its waters from the shore (which is evidenced by the drift wood flowing always in the middle of the channel of the stream); hence the water, after depositing part of its load near the shore, is again made capable of carrying it by the increase of its velocity, when it again gets near the middle of the stream, and thus the central mass of water is continually made capable of taking up from the bottom, the excess of load dropped by the shore currents. At the mouth of the Pass, the angle of rest of the deposit or the natural slope is not yet attained. Here the shore currents are continually dropping the surplus load which their diminished velocity is unable to hold up, and thus the shores of the Pass are being constantly built up in the Gulf, and narrowed in and brought to the surface of the water, where with reed grass, marine plants, etc., they are gradually converted into dry land.

THE RIVER NOT SUDDENLY CHECKED BY THE GULF.

It is a popular fallacy to imagine that the Gulf presents a barrier to the onward flow of the stream at the mouth of the Pass. On reflection, it must seem reasonable that a river should flow with less friction between walls of water than between walls of earth. At the bar, the river has its banks of earth no longer, but it still flows between banks of salt water, and over a bottom of brine instead of mud. It has no longer a descent of a few inches to the mile however, and hence must maintain its current in the Gulf simply by momentum. Friction on its sides and bottom finally brings it

to rest; but while its momentum lasts, the widening out into the sea and the final obliteration of the river will proceed very gradually.

That a stream will preserve its individuality for a great distance, while flowing through the sea or through another body of water, can be proven by every river which enters the ocean with a strong and consequently deep volume. The upper Mississippi preserves its identity for a score of miles after having entered the grand channel of the main river, and the dividing line which separates its clear waters from those of its more powerful neighbor can be distinctly traced, in flood time, far below St. Louis. The South-west Pass current in flood time, can be detected twenty-five miles from the land.*

THE TIDES NO DISADVANTAGE.

If the truth be once impressed on the mind that the river maintains, for some distance, a distinctive channel through the Gulf, the effect of the feeble tides at the mouth will be more clearly comprehended. These average less than fourteen inches in height, and while they simply act to raise and lower the fluid channel through which the river flows after leaving the land, they really oppose no barrier to its onward progress. The average velocity of the current is maintained; the retardation due to the flood tide being compensated by the increased speed induced by the ebb.

IMPROVEMENT BY JETTIES.

Jetties are simply *dykes* or *levees under water*, and are intended to act as banks to the river, to prevent its expanding and diffusing itself as it enters the sea.

It is a notable fact that where the banks of a river extend boldly out into the sea, no bar is formed at the entrance. It is where the banks or *fauces terræ* (jaws of earth) are absent, as is the case in delta forming rivers, that the bar is an invariable feature.

The bar results from the diffusion of the stream, as it spreads out fan-like in entering the sea. The diffusion of the river being the cause, the remedy manifestly lies in contracting it, or in preventing the diffusion.

---

* During a calm day and large discharge, river water can be obtained for many miles outside the bar, on the surface, and to a depth below equal to the mean depth of the bar. (Humphreys and Abbott, Physics and Hydraulics of the Mississippi River—Appendix, page 18.)

A glance at the accompanying map of the Southwest Pass reveals the narrow and uniform width of the Pass, until it is within about seven and one-third miles of the bar, which is about three miles beyond the land's end. In this seven and one-third miles, the river is building up and extending its own banks into the sea, at the rate of 8 or 9 inches per day. Above this seven and one-third miles, its work is finished. *Its jetties* are completed by its own forces, and will probably never change their location, although every time the stream overflows them, fresh deposit will raise them still higher. It is therefore, evident that the river itself is continually employing the jetty system, and that nature makes parallel, and not converging jetties.

WHY THE BAR WILL NOT ADVANCE IF JETTIES ARE CONSTRUCTED.

The surveys of Talcott 40 years ago, and those recently made by the Coast Survey, confirm what the reader would naturally infer, viz: that as the river builds up and finishes its jetties the bar travels seaward; that the bar moves out not as the cause, but as the effect of the jetty building of the river. $7\frac{1}{3}$ miles above the bar the natural jetties are finished and narrowed to their normal width of 1,250 feet, and there the pass is 60 feet deep in consequence. The bar was once unquestionably where this depth of 60 feet now exists. From this point the river gradually widens out to the sea, like a fish's tail, and the current gradually diminishes from four and one-third feet to about three feet per second, at the bar, and to zero some twenty miles beyond in the Gulf.

Since the white man has known the river, this distance between the bar and the narrow and completed banks of the pass above has been the same, viz: $7\frac{1}{3}$ miles. For eleven miles above, the pass presents the same narrow and deep characteristics. The bar has marshalled the way through ages past to the Gulf, and the natural jetties have been built up at exactly the same rate of speed, and have constantly kept the bar seven and a third miles in advance.

It is evident that, as the natural jetties advance, the bar is slowly eroded away. The up-stream part of the bar is gradually cut out and deposited further out in the Gulf. A little reflection will show that there must be some strange connection or influence existing between the finished part of these jetties and the bar, that the distance between them should remain so constantly the same.

Evidently the volume and current passing out between the finished jetties or banks where they are 1,250 feet wide, are so great that the bar cannot form any *nearer* than seven and one-third miles distant; and it is just as evident that this volume and current are not sufficient to make the bar form at a greater distance.

Now suppose that by artificial means these natural jetties could be suddenly extended seven and one-third miles out to the bar. The volume of water would be almost, if not exactly the same, and so would be the current. Instead of passing over the bar as it now does, at three feet, per second, it would pass out from between these artificial jetties at the rate of over four feet per second. This artificial and parallel construction would give the stream at the present bar the width, depth, velocity and volume, almost exactly, which it has to-day, seven and one-third miles above the bar. *Could the bar again re-form afterwards nearer than seven and one-third miles from the end of these artificial jetties?* Would there be less than 60 feet depth between them, as there is now between the natural ones? Suppose there was no literal current or Gulf stream to carry away the sediment, the bar would then certainly form again, *but when?*

At the rate it has been going out for the last forty years it would take the river 65,000 days, or 178 years, to extend its jetties from where they are finished, out to the present crest of the bar. All these years will be required to build up its foundations in the Gulf before it can complete its jetties to the present bar. Is it not evident then that 178 years hence, if the river be left alone, the bar will then be seven and one-third miles in advance of its present location? Is it not equally evident, if man should do in three or four years what it will require the river 178 years to do, that when the bar reappears it will be after the lapse of centuries because it *must be* located at least seven miles beyond the artificial jetties, and where the water is now several hundred feet deep? Even if there be no currents whatever to distribute the sediment into more profound and distant depths, we will have gotten so far in advance of the bar forming power of the river, that it will require centuries for it to overtake the work of man, and again build up its bar, for this must be done in greatly increased depths.

WILL JETTIES STAND?

One of the chief reasons urged against the jetty system is that they cannot be made to stand at the passes.

Their permanency will depend mainly on the skill and experience of the engineer who builds them. Works of this kind are constructed in various ways, according to the nature of the foundations on which they will rest and the casualties to which they will be subjected. To construct them wholly of stone on the bars of the Mississippi would be the sheerest folly. To build them of piles and planks would be equally unwise. The river itself is daily teaching us that it is able to construct jetties of sedimentary matters which the river transports, which are imperishable and constantly increasing in strength. On its banks are found millions of young willows and poplars which, properly formed into fascines, and securely interwoven in large masses, and sunk with stone in the line of the proposed jetties, and securely held in position by huge blocks of beton or concrete, which is but little heavier than the sediment itself, will soon become filled with sedimentary deposit, and form artificial banks indestructible as those nature is daily building at the passes.

This system of construction is being successfully practiced in Holland and elsewhere, on foundations of a character quite like that with which we have to deal. It is idle to predict the impossibility of making jetties stand on a bottom so firm as to hold ships when aground, against the most powerful tug boats that can be procured, and against the severest winds that sweep the Gulf.

MUD LUMPS.

The sedimentary matters brought to the Gulf by the river are deposited in proportion as the current diminishes. The silicious and heaviest particles fall first; the lighter ones are borne much farther seaward before falling. Consequently these lighter matters fall as soft as snow to the Gulf bottom first, and are afterwards, by the bar advance, covered by the heavier ones. Immense quantities of microscopical vegetable matter fall with the light sediment and chemical changes occur in consequence of their contact with the salts of the sea. As decomposition progresses beneath the more recent deposits, gases are produced, and following the lines of least resistance when liberated, they come to the surface. The accumulating weight of the deposit at the bars causes the creamy sediment which first fell to the bottom, and in which these gases are generated, to follow their track to the surface. If this discharge of gas and soft mud occur in the channel, the mud is gradually swept to the sea without man's knowledge; but, if it be in

shallow, and consequently still water, the mud remains around the craters and continued discharges elevate the mounds thus formed, until they are sometimes more than one hundred feet in diameter and fifteen or twenty feet high. A mud lump rarely occurs except near the bar, which indicates that, as the bar advances, the pressure causes the discharge of gas and mud to be made, after which the power of further discharge at that particular locality is forever gone.

These mud lumps have been used to frighten persons not familiar with the subject into hostility to the jetties, on various ridiculous pleas. Whereas if one rose in the line of jetties no better work could be desired at that spot, and if it came up in the channel dredging would certainly remove it, if the current did not. Persons of great experience assert that but one was ever known to rise in the channel, and even that one is of doubtful authenticity. By those who are familiar with the facts, the mud lumps are deemed the most ridiculous absurdity yet advanced against the jetty system. The assertion that they possess any lifting power is utterly without foundation.

ARGUMENTS AGAINST THE JETTY SYSTEM.

One of the most earnest opposers of the jetty system is Major C. W. Howell, United States Engineers, who designed and strongly advocates the Fort St. Philip canal. The following extracts are from a letter addressed last May, by Major C. W. Howell, United States Engineers, to Captain J. H. Oglesby, President of the New Orleans Chamber of Commerce. Speaking of the jetty system, he says:

"The theory is attractive from its apparent simplicity, and for the same reason is the first to claim the attention of dabblers in hydraulic engineering, who either do not know, or else lose sight of the conditions essential to its successful application. The principal of these conditions are two: 1. That the character of the bed and banks of the river, at the point of application, be such that scouring will be effected in the bed, in preference to the banks—in other words, the banks must be firm enough to withstand the action of the current, and the bottom yielding enough to permit scour.

"The second condition is, that there shall exist a current (littoral) passing the outer extremities of the jetties perpendicular to them, capable of sweeping to one side or the other all deposit made about the jetty heads and tending to form a new bar outside.

No such current has been discovered at the mouth of the Mississippi, although carefully sought for. In default of it, jetties would have to be built further and further out, not annually, but steadily every day of each year, to keep pace with the advance of the river deposit into the Gulf, provided they are attempted, and the attempt warranted by having the relative character of bed and banks favorable.

"For the reasons that these two conditions are not to be found at the mouth of the Mississippi, careful engineers have time and time again pronounced the application of jetties at either Southwest Pass or Pass a l'Outre, not worthy of trial *at Government expense*. If enthusiastic jetty men wish to pass from theory to practice, they can always gain consent to spend *their own money* in building jetties at Southwest Pass, and if they succeed in doing good, they will have fair claim on Government for recompense."

* * * * * * * * *

"Jetties have been attempted there, and not only reported a failure by the inspecting officer, but abandoned by Messrs. Craig and Rightor, who made the attempt—the full particulars of this may be found in Ex. Doc. No. 5, Ho. of Reps., 36 Cong., 2d Sess. The practical experience gained by that failure, I presume, will deter the Government, though it will not deter adventurous jetty men, from sinking more money in such attempts."

MAJOR HOWELL'S FOUR ERRORS.

Major Howell was doubtless not aware that he was making four misstatements in his letter to Captain Oglesby. They are as follows: 1. That the banks of the passes will scour away sooner than the bed of the stream. 2. That there are no currents capable of sweeping to the one side or the other, the river deposit beyond the proposed jetties. 3. That "careful engineers have time and time again pronounced the application of jetties at these passes unworthy of trial *at Government expense*." 4. That the jetty system has once been tried at the Southwest Pass and proved a failure.

The idea that the banks will be scoured away is based upon the false assumption that the water will be permanently raised above the jetties. If this were true it would simply create the effect of a flood, and those who are not engineers know that the way the banks of the passes are built up above the ordinary surface level of the river, is by the overflows. Where there are no levees, every overflow contributes to the elevation of the bank of the stream. Each time the banks of the passes are overflown, the reed-grass and plants on their marshy surfaces not only prevent

abrasion, but they check the flow of the current and cause the deposit which is held in the water to be dropped on the banks. With parallel jetties five miles in length, it would be impossible to raise the water five inches, and any temporary elevation would subside with the deepening of the channel.

Major Howell's first statement is therefore evidently an error. The following paragraph from the elaborate report of Humphreys and Abbott (Phys. and Hyd. of Mississippi River) page 449, completely disproves his second statement:

GULF CURRENTS DO EXIST.

"The investigations of the Coast Survey have also shown that the tidal wave approaches the mouths of the Mississippi from a southerly direction. With this tidal wave there is near the coast a tidal current, in the same direction. The tidal wave lifts up the current in the gulf, and the tidal current passes under it, though checking it to some extent in so doing. The direction of this tidal current is modified by its contact with the river current, and to a greater degree by its contact with the outer slope of the bar deposit. In the case of the Southwest Pass, a flood tide brings a current from the southeast, which is changed to a southwest direction, more westerly than that of the river current, by the bar deposit along the eastern side of the mouth of the pass. The ebb tide is accompanied by a current from the opposite direction, which is similarly diverted by the deposit on the western side of the mouth of the pass, the direction being more southerly than the current of the river. Winds may change the direction and force of these currents, which, in mid-river current, at a depth of forty feet, are shown by the observations to vary from three-tenths of a foot to two and five-tenths feet per second, the mean being about five-tenths of a foot. *As a velocity of five-tenths of a foot per second is sufficient to transport the material of which the bar is formed, the action of the gulf currents in carrying into deeper water the material pushed by the river into the gulf is evident.*"

JETTIES HAVE NEVER BEEN TRIED AT THE MOUTH OF THE MISSISSIPPI.

The following extract from the same work (being a foot note on page 455) disproves the other two statements made by Major Howell:

"Attention should here be directed to the fact that *the plan of jetties has not really been tried at the mouth of the Mississippi*, as the contractors merely built one insecure jetty of a single row of pile planks, about a mile long, whereas *the Board of* 1852 *recom-*

mended jetties five miles long on each side of the channel, each fourteen and a half feet wide, composed of piles two feet apart. The plan has been tried, however, at the principal mouth of the Rhone, a delta river like the Mississippi, and has effected the desired increase of depth."

The italics, which are not in the report, are used here to impress these facts more fully on the memory of those who have been continually making counter statements.

U. S. BOARD OF ENGINEERS OF 1852 RECOMMENDED JETTIES.

The Board referred to by Humphreys and Abbott, in this paragraph, was composed of Captain Latimer, Captain Chase, and Generals Barnard and Beauregard. We see, therefore, that "careful engineers" *have recommended* the trial of the jetty system for the mouth of the Mississippi; and prior to the date of Major Howell's letter we believe no engineers of note had reported against them.

Humphreys and Abbott were certainly justified in saying that "the plan of jetties" had not been tried there; for all engineers know that the application of that system to any river mouth opening into the sea as the Mississippi does, with no banks above water, absolutely involves the construction of *two* jetties, one on each side of the stream; only *one*, however, an insecure pile plank dam on *one side* of the mouth, seems to have been sufficient to justify Maj. Howell in speaking of it *in the plural.*

This statement, made without any qualifying explanation whatever, and reiterated again and again by the advocates of the canal, has served more than any other one erroneous statement to confuse the judgement of people respecting the jetty system, and to array them in hostility to the only proper method of solving the problem at the mouth of the river.

MAJ. HOWELL RECOMMENDS JETTIES AT THE MOUTH OF THE BRAZOS.

Although Maj. Howell is so violently opposed to the jetty system at the mouth of the Mississippi, he finds all the conditions required for their success two or three hundred miles west of the Passes.

In a report to Hon. Galusha A. Grow, President of the Houston & Gt. N. R. R., dated March 12, 1874, he recites the conditions which made the improvement of the Salina mouth of the Danube so successful and says:—

"All the conditions stated are similar to those observed at the Brazos, except as to the tides, which are favorable to the latter."

The littoral current which he deems so important for jetty success (but which is not really essential), he finds to the east of the Brazos near the Texas coast. But where it comes from, or goes to, is passing strange, as, according to Maj. Howell, there is none at the Passes of the Mississippi.

The Major says in his report to Mr. Grow of this littoral (or shore) current; "It was inferred that a current did exist, from there being a strong gulf stream sweeping up from the Carribbean Sea along the Mexican coast, at an unascertained distance from the Texas coast and out through the Florida Strait."

"Our own observations," he continues, "for this current were only made at the surface and at depths of six and twelve feet. They were made with a fair south-west wind and resulted in finding a current to the north-east, along the coast," * * * "During the prevalence of strong southerly or easterly winds, the velocity of this current is undoubtedly as great as two miles per hour." He assures Mr. Grow also that "Application of the jetty system has been made at many points on our lake coast, and with success;—vide reports of the Chief Engineer U. S. A."

Maj. Howell's report is accompanied with a map of the mouth of the Brazos, with two straight jetties, not parallel, but converging at the bar.

CHIEF OF ENGINEERS' ARGMENTS REFUTED BY HIS OWN TESTIMONY.

THE DEAD ANGLE THEORY.

General Humphreys makes an elaborate argument (Ex. Doc. House Rep., 1874, No. 220), to prove that jetties at the Southwest Pass, to produce 28 feet, will require an annual extension of 1,200 feet.

The following extracts will fully explain the foundation upon which his arguments is based:

* * * "The first, the ascertained fact already mentioned, that throughout the whole course of the river there is a mass of earthy matter pushed along the bottom of the river (not suspended in the water), moving at a much slower rate than the current of the river.

* * * * * * * * * *

"The second is the ascertained fact that, where the fresh water current of the river meets the salt water of the Gulf, the fresh water rises upon it, and creates a dead angle of salt water on the seaward side of the bar; and when the earthy matter pushed along the bottom of the river arrives at this point, the fresh water having risen from it, there is no longer any pushing force to keep the earthy matter in motion. It remains in the still salt water, forming an accretion to the bar." (See page 9, Ex. Doc. 220.)

"'The current in the Southwest Pass is quite equal to pushing this material along the bottom; but when the river water begins to ascend upon the salt water of the Gulf, the rolling material is not carried with it, but is left upon the bottom in the dead angle of salt water. A deposit is thus formed, whose surface is along or near the line upon which the fresh water rises on the salt water as it enters the Gulf. *This action produces the bar.*'" (See Humphreys and Abbot's report, p. 446.)

"Now, it is obvious that the materials rolled by the currents upon the bottom will be arrested as soon as they reach this dead angle, or space without currents, and that the upper surface of the new bar will be coincident with the slope at which the river waters incline upward." (Gen. Newton, Ex. Doc. 220, p. 29.)

To sustain Gen. Humphreys' theory of bar formation and advance, it is absolutely necessary to establish two facts, which are assumed as the basis of the whole theory: First, that on the outer slope of the bar a "dead angle, or space without currents," exists between the river water and the bottom; and second, that the material to form the bar is "pushed" along the bottom.

Humphreys and Abbot say, on page 449 of their report:

"As a velocity of 0.5 of a foot per second is sufficient to transport the material of which the bar is formed, the action of Gulf currents in carrying into deeper water the material *pushed by the river* into the Gulf is evident." [The italics are mine.]

Hence, if the fact be proven that this angle of salt water is not dead, but is swept by currents exceeding this velocity of half a foot per second, it must then be evident that the pushed material does not find a "space without currents" on which to rest, and that it cannot come to rest as stated.

In Appendix G of Humphreys and Abbot's Report, cxxvi, Prof. Forshey, who had been engaged in "Current Measurements at the Southwest Pass," says: "We have a velocity *at the bottom* on the bar, full two miles outside of the land, of two feet per second." The words "at the bottom" are put in italics by Prof. Forshey. The velocity recorded by him is four times as great as that required to keep in motion the material "pushed by the river" along the bottom.

On page exxix, and following, of same Appendix, we find results of current measurements on the outer slope of the bar in this dead angle, as follows:

Date.	Depth.	Velocity.
1859, May 12	25 feet	1.05 feet per second.
" 12	40 "	1.22 "
" 14	25 "	1.25 "
" 14	40 "	1.18 "
" 16	25 "	3.33 "
" 16	40 "	2.22 "
" 20	25 "	1.85 "
" 20	40 "	2.00 "
" 26	25 "	1.33 "
" 27	35 "	2.25 "
Sept. 5	22 "	.92 "

The average of these observations is nearly $1\frac{3}{4}$ feet per second, or more than three times the velocity that Humphreys and Abbot tell us is sufficient for "carrying into deeper water the material pushed by the river into the Gulf."

If these quotations be not sufficient to disprove the existence of a space without currents on the outer slope of the bar, the extract before alluded to in answering Captain Howell's statements, and taken from page 449 of Humphreys and Abbot's report, would be ample to show that this dead angle is continually swept by currents abundantly sufficient to move the deposits.

It only requires common sense, without engineering lore, to see that these conditions are entirely inconsistent with the assumed "dead angle or space without currents."

As a dead angle or a space without currents constitutes one of the two conditions, absolutely necessary to sustain General Humphreys' argument, it will be seen by this disproof of its existence, from testimony which he cannot impeach, that his statement that the bar will advance under the effect of the jetties at the rate of 1,200 feet per annum, is utterly without foundation. After thus completely disproving one of these two "facts" on which his argument rests, it is needless to discuss the other, as his position cannot be sustained unless both exist.

THE LAWS OF GRAVITY IGNORED.

The bar at the Danube, having failed to advance in accordance with the "dead angle" theory, under the influence of the jetties,

it is absolutely necessary to show some remarkable difference between that stream and the Mississippi; otherwise this favorite theory, based upon the revelations of Prof. Forshey's exploring keg, and so authoritatively set forth on page 446 of Humphreys and Abbot's report, must be exploded. Accordingly, the reason why the bar *does not* advance at the Danube jetties, and why it *must* advance before those of the Mississippi, is thus stated on page 6, Ex. Doc. 220:

"From the foregoing it is apparent that the Sulina bar of the Danube has no resemblance to the bars at the mouth of the Mississippi river, and that what they have been dealing with in the improvement of the Sulina is a bar or shoal derived chiefly from the deposit of *earthy matter held in suspension*, and not *earthy matter pushed along the bottom of the bed of the Sulina.*"

The specific gravity of the matter suspended in the Danube is two and a half times the weight of water, or nearly twenty-eight per cent. heavier than that in the Mississippi. Does it seem reasonable that in the stream in which the sediment is *heaviest* there should be so very little pushed on the bottom, while *enormous quantities* are pushed along the bed of the stream in which it is *lightest?* This statement of the Chief of Engineers is simply an assertion; advanced not only without proof, but in disregard of the laws of gravity.*

ERRONEOUS STATEMENT OF MISSISSIPPI SEDIMENT.

Gen. Humphreys, on page 4, Ex. Doc. 220, makes the following statements:

"The discharge of the Danube, in flood, is about 333,000 cubic feet per second; in low water, about 111,000 cubic feet per second. The discharge of the Sulina, in high water, is about 24,000 cubic feet per second; in low water, about 8,000 cubic feet per second.

"The South Pass of the Mississippi discharges, in high water, about 83,000 cubic feet per second, and in low water, about 25,000 cubic feet per second, and carries to the sea ten times as much earthy matter as the Sulina branch, almost the same quantity as the Kilia branch, and nearly two-thirds as much as the whole Danube."

---

*On page 33, Ex. Doc. 219, the specific gravity of the *matters in suspension* in the Danube is stated to be 2.5; while that of the Mississippi is stated in Humphreys and Abbot's report, page 148, to be 1.96

These statements create the idea that the sediment in the Mississippi in each pass is much greater than in the Sulina, and hence jetties at our passes will be impracticable. It is proper, therefore, to correct them.

The mean daily discharge of the Danube for ten years is given by Sir Charles Hartley at 207,000 cubic feet per second. The South Pass, as will be seen by the quotation above, discharges about one-third of this amount, say 69,000 cubic feet.

Sir Charles Hartley declares, on page 216 of Trans. of the Inst. of Civil Engineers for 1873, "that *the amount of deposit at the various mouths of the Danube was almost directly in proportion to the volume of water issuing from them.*"

We have shown that *by weight* the Danube's suspended matters are greater; and a foot note on page 119 Ex. Doc. 220, states that *by volume* they are nearly the same as in the Mississippi.

From these facts it remains for General Humphreys to explain how the South Pass, discharging but *one*-third of the volume of the Danube, can carry to sea *two*-thirds as much sediment.

Again, the Sulina Pass discharges two twenty-sevenths of the entire Danube, or 15,331 feet per second, which is more than one-fifth of the discharge of the South Pass; therefore the South Pass *cannot* carry to sea "*ten times*" as much sediment as the Sulina.

SEDIMENT OF DANUBE HEAVIER AND EQUAL IN VOLUME.

These statements simply create doubt in the minds of those not familiar with the subject, by conveying the idea that the Danube is comparatively a clear stream, when, in reality, its waters are charged with an equal volume of sediment, and heaver in character than that of the Mississippi. The quantity of sediment of each outlet depends upon the quantity of water issuing from that particular outlet in either river, and such statements have a bearing only upon the *cost* of the jetties needed at either pass, and not upon their practicability. Sir Charles Hartley's argument in favor of the Sulina Pass was simply that the smaller pass involved less expense because its bar was less distant from land, and there being a less amount of water issuing from it the works needed to control the stream would be less costly. Gen. Humphreys recognizes this fact when he declares that jetties for the South Pass will cost $4,150,000, and an annual cost of $670,000 for maintenance,

or the equivalent of an investment of $15,250,000, while those at the Southwest Pass he estimates as equal to an investment of $23,000,000.

By the terms of my proposal I am cut off from using the South Pass.

The jetties at the mouth of the Rhone are referred to on page 29 of the report, as follows, evidently with the intention of weakening confidence in the proposed jetties:

"The disappointment suffered from the application of the jettee system led to the construction of a lateral canal, connecting the Rhone with the Gulf of Foz, and having a depth of twenty-three feet."

Sir Charles Hartley stated to me in person, that in case this work at the mouth of the Mississippi is undertaken, it will be important to extend the jetties at once with all speed to the deep water, to lessen the cost, as the bar would advance more rapidly until this shall have been accomplished. This is the opinion of several other distinguished engineers, who do not believe any rapid advance of the bar will occur afterwards. In view of this fact, the following, from page 29 Ex. Doc. 220, may serve to show why the jetties at the Rhone did not succeed:

"Upon the Rhone, when the jetties were completed, in 1852, the bar was about seven-eighths of a mile in advance; in 1863 this advance was nearly one and three-fourths miles, the progress during this interval having been three times the ordinary rate."

If the bar was seven-eighths of a mile in advance of the jetties when they were completed, this fact should suffice to explain the cause of the disappointment. The fact is attested by Humphreys and Abbot, in their report, which bears date 1861, in foot-notes on pages 452 and 455, that these jetties effected the desired increase of depth. They were therefore of value for seven or eight years, although not built out to the bar.

Another statement in this report deserves notice. General Newton declares, on page 34 Ex, Doc. 220:

"The rapid extension of a pass by jetties, though under all circumstances prejudicial to the discharge through it, would not be so soon felt in its consequences in the ordinary river: but at the Mississippi delta such an operation might inure to the rapid deterioration or ruin of the pass, and this is the reason why the application of the jettie system to these mouths must sooner or later wear them out by forcing the waters into other channels."

JETTIES TEND TO INCREASE THE FLOW AND DEEPEN THE PASS.

Sir Charles A. Hartley, in direct opposition to General Newton, declares, on page 217, Reports Institute of Civil Engineers, 1873, that the absence of training works or jetties at a Pass, where the flow is increased, tends to the injury or shoaling of the Pass, while jetties tend to increase the flow into the Pass, and consequently to deepen it.

Of all arguments yet advanced against the jetties, this certainly is one of the weakest and most indefensible. If it could possibly occur that the jetties obstructed the Pass by being wrecked and carried away, as some have thought possible, and lodged on the bar, General Newton has himself supplied the proof that such casualty could not result in injury; for he says (first paragraph, page 34):

"The same reasoning applies to the passes, which, perforated through the most yielding alluvions, will always suffice to discharge the river, and should one by some obstruction be impeded in its discharge, the others enlarge their cross-sections to supply the emergency."

We learn, on page 6, Ex. Doc. 220: * * "Even at the mouth of the smallest pass the quantity of both kinds of deposit matter is enormous."

Prof. Forshey has assured the committee that the amount *pushed* on the *bottom* of the Mississippi was fifty times as much as that carried by it in supension. And the Chief of Engineers, by declaring the quantity of *both* kinds of matter to be enormous, leads his readers to believe there is but little difference in the quantity of either. On page 149 of Humphreys and Abbot's report, the estimated quantities are stated as equal to one square mile twenty-seven feet deep of *pushed* material, and one square mile two hundred and forty-one feet deep of *suspended* matters, the quantity supposed to be *pushed* being about *one-tenth* of the whole.

HOW THE WONDERFUL DISCOVERY WAS MADE.

On page 149 of Humphreys and Abbot's report the means employed to make the discovery that this enormous amount of matter is being pushed on the bottom is thus described:

"A keg, similar to that used in collecting water below the surface, was sunk to the bottom of the river. The current immediately overturned it, and the valves opening allowed the water to pass freely through. After remaining a few minutes it was drawn suddenly up, and was invariably found to contain material such as gravel, sand and earthy matter."

Prof. Forshey has informed us that no investigations or experiments with a keg, or by any other means, were ever made by Humphreys and Abbot to determine this question, and that the principal hydrometrical data in Humphreys and Abbot's report were supplied by himself. To him belongs the honor of discovering, by means of the keg described by Humphreys and Abbot, the enormous amount of material pushed on the bottom, and "of which the bar is formed"; therefore, upon his investigations mainly rest the fabric of arguments and conclusions respecting the untenable "dead angle" theory of bar advance, published by General Humphreys.

AN ERROR IN PHYSICS.

On page 5, the Chief of Engineers says:

"Now, the earthy matter held in suspension by the Mississippi River is mainly kept in suspension by the horizontal and vertical irregularities of the bed (see page 139 Report of Mississippi River), which constantly stir it up so long as these irregularities exist. When these vertical and horizontal irregularities diminish the quantity of suspended matter diminishes, some of it falling to the bottom; and when these irregularities cease altogether the greater part of the suspended earthy matter begins to fall to the bottom."

This is not the place to prove the fallacy of this statement, although I cannot let so grave an error in physical science go forth from such distinguished authority without protest. It is a necessary sequence, however, to the assertion that there exists no relation between velocity and quantity of sediment in suspension. If velocity be not the cause of suspending it some other reason had to be given; and General Humphreys has stated one in direct conflict with every-day facts observed in aqueducts and canals devoid of these irregularities. In India, where canals are located through alluvial districts, and are supplied with water holding sedimentary matters, it becomes necessary that a current be created sufficient to keep them from depositing, while to prevent scour the current must be limited strictly to such velocity.

Sediment is unquestionably taken up and kept in suspension by the upward motions imparted to water by the series of curves which its atoms are continually making while flowing over its bed. These curves are created by the smoothest beds, and result from the friction of the water in contact with the bottom. Hence, no

bed of a stream can be so smooth as to prevent the suspension in it of loose or disintegrated particles of sand and earthy matters when sufficient velocity of current is attained. As the rapidity of the stream increases it is enabled to suspend larger particles, and even gravel may be raised some distance from the bottom.

PERSONAL EXPERIENCE IN THE DIVING-BELL.

Frequently in the upper part of the river, in low water, the current cuts tortuous channels down many feet lower than the dry surfaces of the sand bars. By the floods these channels are quickly obliterated and filled up when they cross the main current of the full river. During one of these floods I had occasion to descend to the bottom in a current so swift as to require extraordinary means to sink the bell; and although the sand was apparently drifting like a snow storm at the bottom, sixty-five feet below the surface, and was doubtless being swept off of bars that were dry in low water, I feel confident it was really afloat or suspended. This was near Island No. 10, and in a current much more rapid than any that sweeps by New Orleans. My boat was carried away the next day by the drift-wood; and this constitutes my only experience on the river bottom in *flood time*. Frequent examination of the bottom at ordinary stages of water enables me to declare that sand and other sedimentary matters are carried in suspension, and not *pushed* along the bottom. Drift-wood, balls of clay, or other aggregations of earthy matters are doubtless rolled or *pushed* along on the bed, and sometimes gravel and boulders; but the amount of these passing New Orleans is very small. Gravel and boulders never reach there. That which was once the largest item, viz: sunken drift-wood, is yearly diminishing, as the clearing of the lands bordering the river increases.

On page 5, Ex. Doc. 220, General Humphreys states: "In the vicinity of New Orleans the material thus dropped, which is drifting along the bottom, is the same kind of material as the sediment held in suspension, no coarse material being carried or pushed by the river past this point."

This is simply assertion without proof. Sand, which is the heaviest material carried, is found in the river at all depths from the surface to the bottom.

SAND IN THE SURFACE WATER AT THE BAR.

Gen. Humphreys says, on page 5, that "the horizontal and vertical irregularities of the bed cease almost entirely, where the

Southwest Pass begins to widen 7.3 miles from the crest of the bar." Yet, without these irregularities of the bed, we find the water capable of sustaining sand near the surface on the bar, as is shown by the following, from Humphreys and Abbot's report, Appendix A, page xviii.) :

"Experiments were made on the nature and quantity of the sand, by sinking a closed box, pierced on opposite sides with holes of unequal diameter, the larger orifices being placed up stream. The water, in passing through, had its velocity diminished, and deposited the coarser particles held in suspension. In this manner the sand of the bottom and surface currents was obtained in different parts of the delta. The sand of the bottom is a little coarser than that from the surface."

SEDIMENT IS NOT PUSHED ON THE BOTTOM.

In sinking the large caissons of the bridge at St. Louis, they were suspended like huge diving bells near the river bottom, for several days before they finally sank into and entered it. They were illuminated, and I was repeatedly in them, and if any such pushing process had been going on there, I would have discovered it. Five miles below Cairo, I searched the river bottom for the wreck of the "Neptune," for more than sixty days, in a distance of three miles, without finding any material pushed along the bottom. My boat was held by a long anchor line, and was swung from side to side of the channel, over a distance of 500 feet, by side anchor lines, while I walked on the river bottom, under the bell, across the channel. The boat was then dropped twenty feet further down stream, and I then walked back again, as she was hauled towards the other shore. In this way I walked on the bottom four hours at least, every day (Sundays excepted) during that time. The bottom there is of gravel, cemented into large masses with oxide of iron and earthy matters; and if any material had been *pushed* along the bottom it could not have escaped my observation. There was not even *drifting* on the bottom there. At Plumb Point, 100 miles below, I had even a still more protracted search in the same manner, for the "America." Besides these, I have been on the river bottom on not less than five or six hundred other localities, and I know that no such material as forms the bars of the passes is *pushed* on the bottom of the river in any such quantity as is requisite to form them, or to serve as a basis for the calculations of bar advance under the influence of the jetties, as made by General Humphreys. Nor is it necessary

sary to create any such special theory of bar formation for the Mississippi river. The bars at its mouth are not formed by any process of nature which differs materially from that at the mouths of the Ganges, the Nile, the Danube, or any other delta river in the world.

THAT JETTIES WILL DEEPEN THE MOUTH IS ADMITTED.

The whole question really at issue in this matter, is whether the jetties will require to be advaneed 1,200 feet per annum, as Gen. Humphreys deelares, or whether they will not. That *it is practicable to build and maintain them*, and *that they will produce the required depth*, Gen. Humphreys has, I think, never publicly denied. On the eontrary, he has declared on page 455 of Humphreys and Abbot's report, that they *are* correct in theory. On page 455 of the same report is a recital of the recommendations of the Board of 1852, whieh reeommended the trial by jetties, *and only recommended the canal after all other means should fail.* The late Board do not presume to say that they will not deepen the channel. It is simply the diffieulty of eonstructing the jetties, and the neeessity (as they believe) of extending them every year, whieh constitute the ehief objections to the system.

Gen. Humphreys, in the following passage which I have put in italies, evidently concedes the fact, that the jetties will produce the desired depth. On pages 7 and 8 of his latest report (Ex. Doc. 220) he says:

"If we refer to the channel where it is twenty-five feet deep, we fiud the width to be about 4,000 feet; and the mass of the annual addition to the bar being the same, the annual extension on a front of 4,000 feet, instead of being 338 feet, will be about 1,000 feet, and this will be about the annual extension of the bar for a depth of twenty-five feet if the jetties are suitably arranged for that depth. If they are at a greater distance apart, the depth will be less than twenty-five feet. If they be a less distance apart, the depth will be greater, and, the addition to the bar being formed on a less front than 4,000 feet, will have a greater annual extension than the bar formed on that front. *So that in applying jetties to permanently deepening the bar of the Southwest Pass to twenty-five feet, we must expect an annual extension of the bar of about* 1,000 *feet.*

"If the depth to be maintained is twenty-seven feet at low water, or twenty-eight feet at high water, it will be found by a similar process that the annual advance will not be less than 1,200 feet.

"*The jetties may be so arranged as to cause a greater depth than the one required, and thus obviate for a time the necessity of their annual extension*

into the Gulf, but such an arrangement will entail a proportionately greater first cost in their construction. The final result as to cost and depth will be the same whether the jetties be converging or parallel, and the parallel has therefore been assumed as the model in this discussion."

I think no one can doubt, after reading these extracts, that Gen. Humphreys *knows* that the jetties will produce the depth. The only argument made against them is their greater cost, and the necessity of an annual extension of 1,200 feet per annum. The objection as to cost falls to the ground under my proposition, and all that remains is the question, *will the required extension of the jetties be twelve hundred feet per annum*, or any lesser rate of importance?

THE DEAD ANGLE HAS NO EXISTENCE.

The extracts I have given from Gen. Humphreys report, show that his theory of bar formation and the prediction of its annual advance, rest wholly and absolutely upon the existence of "the dead angle," or "space without currents." This "dead angle" theory, which is utterly untenable in itself, I have disproved beyond the possibility of denial, simply by the published testimony of its own author. Without "the dead angle," the *annual* or *constant* bar advance is an absolute impossibility, and from Gen. Humphreys own reports and from them alone, I have proved that the so-called "dead angle" is *a myth*.

The constant advance of the Southwest Pass bar *now*, is because the natural jetties or finished banks of the Southwest Pass, are seven and a third miles distant. Whenever these natural jetties are artificially extended 1,250 feet asunder, out seven and one-third miles, the bar will disappear; and when it reappears, it *must* be seven miles and a third (or very nearly) from the ends of the artificial jetties; and hence, until it does reappear, its *annual* or *constant advance* again is impossible. If there be no Gulf currents, it will reappear in two or three hundred years; and then it will *again* begin to advance constantly.

Admit, however, that such advance of the jetties as Gen. Humphreys predicts, will be necessary, and that it will cost all Gen. Humphreys estimates (one million dollars per annum). The Government retains an ample amount of my compensation to insure such extension, and it will enjoy a deep river until a canal, or better remedy, if needed, is provided. If I fail entirely, I and my asso-

ciates lose *our* money, and the country is no worse off. It does not lose a dollar. If the jetties however, should succeed, the nation secures an inestimable prize—AN OPEN MOUTH RIVER. With so much to gain, and so little to lose in accepting my proposition, can it be decmed wise to decline it?

MISQUOTATION OF MY STATEMENT BY GEN. HUMPHREYS.

Gen. Humphreys declares, on page 10, of the report, 220 Ex. Doc.:

"It has been recently stated by a civil engineer, in a pamphlet concerning the improvement of the mouths of the Mississippi River by jetties, that the amount of sedimentary matter carried in suspension by the Mississippi River is in exact proportion to the velocity of its current; and that as a given velocity of current will keep in suspension a corresponding quantity of solid matter, at a less velocity a certain portion of it will be dropped. To illustrate this he states that—

"'When the Bonnet Carre crevasse occurred, the river below it—107 feet in depth—was shoaled up thirty-one feet, because the volume of water in the river being lessened by the crevasse, was no longer sufficient to maintain the normal current in a channel large enough to carry the entire river; consequently the current below the crevasse slackened, and the excess of load was dropped in the channel until the bottom was filled up thirty-one feet with the deposit. This reduction of channel was sufficient to re-establish the current and prevent further deposit.'"

This verbatim quotation from my letter to Senator Windom, respecting the crevasse, fixes this statement of "a civil engineer" upon me. My real proposition, on the first page, in that letter, is thus stated: "The amount of this matter, and the size and weight of the particles which the stream is enabled to hold up and carry forward depend wholly upon the rapidity of the stream, modified, however, by its depth."

As this proposition is much more brief than the *verbatim* quotation by which this *mutilated* statement of "a civil engineer" is fixed upon me by Gen. Humphreys, it is to be regretted that my real proposition was not likewise given in my own language. By leaving out the words "*modified, however, by its depth*," I am made to appear as ridiculous as though I had asserted that the capacity of the river bed is in exact ratio to its width, *without reference to its depth*. The arguments and tables of velocities of current and quantities of sediment, with which on pages 10, 11 and 12, he demolishes the mutilated proposition he has fastened upon me, show

that the misapprehension of my actual statement has cost the Chief of Engineers much time and labor to refute WHAT I NEVER ASSERTED.

NO RELATION BETWEEN CAUSE AND EFFECT!

General Humphreys continues, on page 10, with the following:

"The first statement is in direct conflict with the results of the long continued measurements made upon the quantity of earthy matter held in suspension by the Mississippi River at Carrollton, near New Orleans, and at Columbus, twenty miles below the mouth of the Ohio, one of the chief objects of which was to determine this very question, whether any relation existed between the velocity and quantity of earthy matter held in suspension. These results prove that the greatest velocity does not correspond to the greatest quantity of earthy matter held in suspension; on the contrary, at the time of the greatest velocity of the current at Carrollton, the river held in suspension but little more sediment per cubic foot than when the velocity was least. When the quantity of earthy matter held in suspension was greatest, the velocity was two feet per second less than the greatest velocity, the quantity of earthy matter in the one case being three times as great as in the other. We find at another time, when the velocity was one-half the greatest velocity, the quantity of earthy matter held in suspension was double in amount."

These remarks are intended to controvert my real statement, and to prove that no relation exists between the rate of current and the quantity of load suspended; for he says one of the chief objects "was to determine this very question, whether any relation existed between the velocity and quantity of earthy matter held in suspension."

Those who are familiar with the best writers on this subject, know that the ability of the stream to suspend its sediment is believed to be *inversely as the depth*. It is a most notable fact, however, that Humphreys and Abbot did not take into account the element of depth in coming to the conclusion, that no relation exists between the velocity and the load suspended. This will be seen by referring to their report (p. 139); and in the above extract, General Humphreys repeats this statement, which he endeavors to prove by deductions drawn wholly from observations upon the velocity of the stream and amount of its load, but entirely omitting one of the important elements in the problem, viz: the variations in the *depth* of the stream.

The most accurately prepared tables of diameters and capacities

of a lot of different sized tubs of various depths, would indicate no relation whatever, between diameter and capacity, if the element of *depth* was ignored. General Humphreys, by leaving out of my proposition this important element, has made me appear as ridiculous as though I had asserted that the capacity of a tub was in exact ratio to its diameter, regardless of depth. His own deductions are as absurd as if he were to assert that no relation existed between the diameters of these tubs and their capacities. The absent element in the problem would establish the relation, which every one knows must exist between diameter and capacity.

He is welcome to such conclusions as he may draw from pondering over *a part* of the elements of a problem, but I must protest against being published as the author of the mutilated proposition which he has been laboring to disprove.

The difference in the character of the bed and banks of the Mississippi at different localities must, of course, exert a modifying influence upon the evidence of relation between velocity of current and matter transported. But nothing can be more certain than that if the current ceased altogether, the load of sediment would drop; and that if the current was restored, the load would again be taken up. The current must therefore be *the cause*, and the suspension of the load *the effect*. If it be the cause, it *must* have relation to the measure or *quantity* of the *effect;* hence, to declare that no relation exists "between the velocity and quantity of earthy matter held in suspension," is to assert that no relation exists between cause and effect. I think, with Gen. Humphreys, that "it is unnecessary to pursue this subject further."

BONNET CARRE CREVASSE SUPPORTS MY ARGUMENT.

Gen. Humphreys says, on page 12:

"This statement, concerning a deposit being formed below the Bonnet Carre crevasse, was made just before the survey of the Mississippi delta was begun, and was carefully investigated in the course of that survey. The subject had an important bearing upon the question of using outlets to reduce the floods. It was found there had been no deposit whatever below the Bonnet Carre crevasse, and that the bottom of the river there was composed of hard blue clay, of older formation than alluvion, and that the cross-section had unquestionably remained unchanged."

I am not prepared to accept the explanation that the difference thirty or thirty-five feet in depth above and below the crevasse,

was due to a stratum or bar of "hard blue clay of older formation" below the crevasse, and not to a deposit resulting from the depletion of the river by that outlet; especially in the admitted absence of soundings to prove that the shoal existed *before* the crevasse. I am also informed by Professor Forshey that this bar "of older formation" was swept away by the next flood after the crevasse was closed!

Undoubtedly at one time, the bars at the mouth of the river were located miles above the present delta, yet the river has scoured through the various strata of blue clay and sand, on which the ancient bars rested, and now sweeps through a channel more than one hundred feet below the highest of the blue clay deposits, and these must have been as difficult to scour through as the one at Bonnet Carre. The sounding lead cannot give reliable evidence of the character of the bed of the river, if there be any such amonnt of material *pushed* along the bottom as Gen. Humphreys claims.

If the facts be precisely as stated, viz: that the diminished depth of the river below the crevasse existed prior to the crevasse itself, it does not at all conflict with the theory advanced in my letter to Senator Windom. The river being already sufficiently diminished in section, there would be no loss of current, and hence no sediment deposited.

The theory set forth in my letter to Senator Windom, and which Gen. Humphreys has misquoted and endeavored to disprove, met the unqualified approval of many of the ablest scientists of America, before it was published. I claim no originality in it, except in applying it to solve the phenomena of the Mississippi River. It gives a simple explanation of the important part performed by the river, in the creation and extension of the banks and bars at the Passes. It conflicts with no ascertained fact whatever, and explains every phenomena presented by the river throughout its delta.

Gen. Humphreys' theory, however, requires a number of physical impossibilities to reconcile inconvenient facts with it, and an amount of inventive talent that cannot fail to be appreciated. For instance, the correlation of cause and effect must be ignored, to sustain the remarkable proposition that no relation exists between velocity of current and quantity of suspended sediment. This, in turn, necessitatess an imaginary bar of blue clay of older formation, to explain away one of the truths which conflict with it; while another stubborn fact has to be accounted for by "the horizontal and vertical irregularities of the bed." Then, to get rid of

the sediment, which, in accordance with this theory, is supposed to fall to the bottom, when these irregularities cease below New Orleans, it becomes necessary to introduce another peculiar conception, the *pushing* theory, by which the river is supposed to push this enormous quantity of sedimentary matter along its bed, and up over the crest of the bar, as a sailor pushes to the scuppers the dirty water on a ship's deck with his squillgee. After this enormous amount of sedimentary matter is *pushed up over* the oozy crest of the bar, it becomes necessary to create the grandest novelty of all, "the dead angle;" or, "this space without currents," which is supposed to underlie the immediate outflow of a mighty river! And finally, when the Sulina jetties flatly disprove the existence of "the dead angle," the laws of gravity are disregarded, and we are gravely assured that, while our sediment is *pushed* along the bottom, that of the Danube, although twenty-eight per cent. heavier, is carried in suspension, and of course cannot fall into "the dead angle"!

THE FORT ST. PHILIP CANAL.

CAPACITY.

It requires about twenty minutes in moderate-sized canals to pass a single boat through a lock, but for large ships, the time requisite to open and close the enormous lock-gates of the proposed canal could not be much less than an hour, including the hauling of the ship into and out of the lock. But even supposing it required half so long, it could then pass but twenty-four vessels per day out of the river, and as many more into it. Such a canal would scarcely suffice to pass out the number of steamships now leaving New York daily, to say nothing of the multitude of sailing vessels arriving and departing every twenty-four hours. If it could be completed in ten years, it would then be found that it had not one-quarter the capacity it would need, and this too, supposing no dredging or repairs should interrupt its constant use.

This fact is partly conceded by its advocates, as they propose that small vessels, of 10 or 12 feet draught, shall encounter the shoals and dangers of the present natural outlet, thus virtually admitting that the capacity of the canal would be insufficient to wholly relieve navigation from its present dangers and delays.

INTERRUPTIONS BY DREDGING, ETC.

The entrance basin, 400 feet long between the river and the lock, would be constantly receiving the deposits of the river, in consequence of the current flowing past it, and would be a continual source of annoyance and delay from this cause.

In the report of the U. S. Engineers on the canal, (Ex. Doc., 113,) it is stated that dredging will be absolutely necessary. On page 10 the report says of the gulf end of the canal:

"As there will be no current through the canal, we must expect silting immediately between the heads of the jetties, due to eddies from the currents through the pass. It is apprehended that shoaling of the entrance to the canal from this cause will not be rapid, but that there will be required, to free the entrance from such deposit as may be made, each year, the service of an ordinary dredge-boat for several days, perhaps weeks."

And of the lock and fore-bay or basin, next to the river, it says, on the same page:

"Slight deposit is anticipated within the lock, the removal of which, quarterly or semi-annually, will be a very simple operation.

"There will be deposit of river silt in the fore-bay of the lock, due to an eddy from the river current. The amount of this deposit cannot be calculated, and it will require occasional dredging to maintain the depth of this entrance to the canal."

While its most enthusiastic advocates make these admissions respecting the inevitable necessity of dredging the east and west ends of the canal and its lock, we may well pause to consider the effects that would result from checking commerce in its flow to and from the vast and productive valley of the Mississippi every time a few days or weeks were required to dredge out the fore-bay, or the lock, or to make repairs to lock-gates and sills, and the like, or to remove the silt from the jetties in Breton bay.

LOCATION UNDETERMINED.

With reference to the location of the canal, the report declares on pages 62–3:

"But it is suggested in order to avoid beds and pockets of quicksand known to exist at some points in this locality, that the precise line of the canal should not be decided upon until a more thorough examination of the sub-strata has been made by borings. It is not improbable that such an examination may indicate the expediency, and perhaps the necessity not only of adopting a curve, or a series of curves, in preference to a straight line for the axis of the canal, but also of selecting other points of termini than those recommended by Captain Howell."

And on page 64:

"8. It is evident from the foregoing that the necessary and unavoidable absence of sufficient data to determine the best location for the line of canal across the peninsula, including its termini, and particularly its debouche by jetties, into Isle au Breton, renders it impossible to make a close estimate of its cost."

THE ULTIMATE COST IS UNKNOWN.

The question of ultimate cost of the work is equally as indefinite as that of location. On this subject, in addition to the last extract, the report declares (page 63):

"2. With regard to the plan submitted by the engineer in charge, he has stated that it was prepared while pressed with other important duties, and that, under the circumstances, it was not possible to perfect all details of the project, or to make the numerous borings which are considered a necessary preliminary to a precise location of the route of the canal through the entire length. The estimate submitted can therefore only be regarded as an approximation to the probable cost of the work."

On page 64, the report also says, with reference to this subject:

"7. The jetties, extending the canal into the deep waters of Isle au Breton Pass, will doubtless require more material than the plan submitted by Captain Howell contemplates; but inasmuch as the length of these jetties, and their cubic contents, depend, to no inconsiderable extent, upon the position selected for them, no very accurate estimate of their cost can be made until the final location is determined upon."

These quotations are all taken from the *majority report*, which favors the canal project.

THE PLANS OF THE CANAL NOT MATURED.

From these extracts it must be evident that General Barnard's emphatic declarations against the scheme, are entirely justified. He says (page 89):

"Surely there is ground here, especially when we weigh the inestimable benefit of an open river mouth, to pause at least long enough for a mature study and investigation, not merely on paper, but by surveys and measurement at the localities, to collect the special data which bear upon the application of the project to them, instead of by a hasty pre-judgment founded on inadequate knowledge, deciding that there is no remedy to the evils but the gigantic and costly alternative of a ship canal."

It is evident, therefore, from the report, that neither the cost of the work, the line of its location, the position of its terminal points, nor the exact methods of construction, have been determined upon by the engineers who advocate the work.

General Barnard, who was the President of the Board, after expressing his faith in jetties as the speediest means of obtaining a permanent deep water channel, thus protests against the canal, on page 91 of the report:

"It is said that 'the time has come' when the needs of commerce demand the canal; but I answer the *time will come* when there will be the same cry for a navigation unimpeded by locks—AN OPEN RIVER MOUTH—which we now hear for a canal. But in whatever aspect the question be regarded, the use of the river mouth for the next ten years is simply inevitable.

"The conditions of the location and execution of a canal have received no adequate study. The plan, boldly and ably, and yet so imperfectly sketched out nearly forty years ago by one for seventeen years my commanding officer or professional associate, W. H. Chase, is yet, in its engineering features, the best plan extant; and the grave objections to that apply with even greater force to the present project, and demand new studies of location and an entire revision of plans of execution. It would be a rash confidence which would contemplate a realized 'Fort St. Philip Ship Canal' earlier than A. D. 1884."

COST OF JETTIES.

The cost of constructing jetties to insure 25 feet of depth is estimated in the report of the U. S. Engineers, on page 73, as follows:

"This consideration of the unstable and treacherous nature of the shoals and banks is necessary in order to fix the mind upon the cost and risk as well as upon the disappointment which would likely attend an attempt, upon such foundations, to construct works to coerce or control the currents of the passes.

"An estimate has been prepared by Captain Howell, engineer in charge, of the jetties described in this report, supposing them to rest upon the natural bottom, without settlement, as follows:

Fascines and ballast, at $5.00 per cubic yard, -	$2,545,220 00
Riprap stone, at $7.90 per ton, - - - - -	2,241,097 60
Total, - - - - - - - - - -	$4,786,317 60

"If settlement and the other probabilities enhancing the cost of this work, as already discussed, be considered, it appears entirely within limits to state that the above estimate should be doubled.'

This would make their cost $9,572,635.20, and to this the Board deem it proper to add the cost of an additional 1,000 feet of extension that would be necessary, estimating that the bar would ad-

vance 250 feet per annum, and that four years would be required to complete the jetties, making a grand total largely over $10,000,000.

The cost of the annual extension of the jetties the Board declares would be $1,613 per linear foot, or for 250 feet $403,250 for each jetty, or $806.500 per annum for this expected advance; or. in addition to the first cost of the jetties, $7,249,500 more, for annually extending them during nine years.

General Humphreys, in his anxiety to prevent a trial of the jetty system, impresses upon Congress (in Ex. Doc. 220) the assurance that the cost of jetties for the Southwest Pass, together with the cost of extending them annually, will be equal to an investment of $23,000,000. In a letter written by him a short time afterwards, and read in the House of Representatives to aid in defeating my proposal to construct them at my own risk, and to maintain them for nine years afterwards for $11,000,000, he undertook to show that I would make some six or seven millions if my offer were accepted. Thus, in his report, he says in effect, "Don't let the United States build the jetties, for they will cost $23,000,000"; and, in his letter, "Don't let Mr. Eads build them, even at half that sum, for he will make six millions on them." Thus, although in absolute ignorance of how I propose to construct the jetties, the Chief of Engineers, while on record that they will cost, if built by the government, $23,000,000, does not hesitate to make plans and estimates for me, and on them to create the impression in Congress that I will make an enormous profit if I undertake the work at my own risk, and at less than half his former estimate, and then wait through a course of eleven or twelve years for my pay; the whole of which is to depend not simply on deepening the water but on maintaining its depth uninterruptedly. This mode of defeating a measure is, I believe, novel in official circles.

PROFESSIONAL OPINIONS.

The advocates of the canal place great stress upon the fact, that six out of the seven officers of the United States Engineer Board recommend the canal, whilst but one, the senior member, opposes it. His reputation among both civil and military engineers is acknowledged in Europe and America to be equal to that of any other one living, and we have no evidence that he does not reflect the views of a majority of his corps upon this important question.

As an evidenee, however, that General Barnard is not unsupported in his opinion upon the value of jetties for improving the mouth of the Mississippi, the following letters from distinguished engineers are appended.

The first is from General James H. Wilson, recently of the United States Engineer Corps, and lately in eharge of the eonstruetion of the United States canal at Keokuk:

NEW YORK, *March* 20, 1874.

James B. Eads, C. E., St. Louis Mo.

DEAR SIR:—Having carefully considered the various plans for the improvement of the mouth of the Mississippi, I have much pleasure in saying that I regard yours, by the use of jetties, as the best which has yet been devised. It will eertainly seeure a wide, deep and commodious channel, which can be navigated with perfect safety, at all times, by the largest sea-going vessels. This ehannel will never be worse than it is now, but will be improved from the time the work is begun, while its full benefits will be realized in a shorter time and at a less cost than is possible by any other method. The works ean be more easily eonstructed, as well as more cheaply maintained, than those necessary to any other plan, and are the only ones which, in my jndgment, satisfy all the conditions of the problem. I feel equally confident that the proposed eanal near Fort St. Philip, even if constructed, would in a few years prove utterly inadequate to the requirements of navigation.

I am sure I need not in this letter discuss the prineiples or precedents upon whieh my judgment is founded, for they have been already ably stated by yonrself, and also by that distinguished man of scienee, General J. G. Barnard, in his report on the St. Philip eanal project. I may add, however, that the improvement aimed at by you is a work whieh, in my jndgment, will do more than any other measure now before Congress to eheapen transportation between the interior and the sea-board; and, as you propose to assnme the entire risk of its snecess. I trust Congress may anthorize you to undertake it at an early day.

Very respectfully yours,

JAMES H. WILSON.

ERIE RAILWAY COMPANY, OFFICE OF CHIEF ENGINEER,
NEW YORK, *March* 21, 1874.

James B. Eads, Esq.

MY DEAR SIR:—I have your favor of 13th, enelosing a description of your proposal for the improvement for the mouth of the Mississippi, and asking for my opinion as to the success of the system of jetties, as eompared with the canal seheme.

Having, during the twenty years whieh I spent in the West, given some attention to the phenomena conneeted with its great rivers, I can say, without hesitation, that the plan you propose has my full approval: and that I have no doubt of the sneeess of jetties, properly located and built, in deepening the channel of the Mississippi River at its mouth.

This opinion is based upon the fact, that you propose to make the river itself do the required work, by simply transfering elsewhere, and intensifying, the forces now performing slowly the action which you require.

I suppose there is no question but that at one time the bar of the Mississippi was above New Orleans. As the river has advanced into the Gulf, it has taken up its bar behind it, and by depositing silt on its shore, excavated the channel to a depth exceeding one hundred feet. This, if I understand it, is what you propose to compel the river to do in two or three, instead of two or three hundred years, by providing, at once, artificial shores.

This being based upon natural laws, and copying exactly the action now taking place slowly, strikes me as much surer and cheaper to maintain than any system of artificial navigation, such as a canal. I have such entire confidence in it, that if you organize a private company, as you propose, to do the work, upon an adequate basis, I should like to become one of your stockholders.

Allow me to suggest that you bring this question up before the Society of Civil Engineers for discussion either, by a paper or otherwise. We have several members who have given attention to this subject.

Respectfully,

O. CHANUTE, C. E.

Mr. Chanute is chief engineer of the Erie Railroad, and constructed, among other important works, the great bridge across the Missouri River, at Kansas City, and is one of the ablest engineers in America.

ST. LOUIS, MO., *March* 12, 1874.

Capt. James B. Eads.

DEAR CAPTAIN:—I have read carefully and attentively the reports of the U. S. Engineers on the improving of the mouth of the Mississippi River, and your own paper on the same subject, and am very thoroughly satisfied of the correctness of the system advocated by General Barnard and yourself.

In a commercial point of view, there is no comparison between the advantages offered by an open channel, one thousand feet in width, and a canal lock, eighty feet wide, while the engineering problems as to the mechanical construction of the jetties, their probable permanence, and their influence on the river channel, have already been very satisfactorily settled, by the success of works on the Missouri River, differing mainly in degree from those proposed by you. Knowing, also, that if unforeseen contingencies present themselves, they will be fully met by the same wealth of engineering resource which has given us the St. Louis bridge, I feel perfectly confident in predicting not only a success, but an early success in case you undertake this work.

Yours truly,

C. SHALER SMITH, C. E.,

President Baltimore Bridge Co.

Colonel Smith has designed and constructed some of the most important works in this country, among which may be named the superb bridge over the Missouri river, at St. Charles. He was formerly in the engineer corps of the army, and has probably as thoroughly practical and theoretical acquaintance with the physics and hydraulics of the rivers of America as any other engineer in this country.

NEW ORLEANS, *February* 25. 1874.

James B. Eads. Esq.

DEAR SIR:—I have resided in lower Louisiana continuously during nearly twenty-eight years, and have carefully observed and studied the Mississippi River during all of that time. I concur fully in the general views set forth by General Barnard, in his minority report on the St. Philip canal, particularly that "*an open river mouth*" "unimpeded by locks," is much to be preferred to a ship canal with locks. I heartily approve of your proposition to improve one of the river mouths, and hope that Congress will adopt it; believing as I do that it will be as successful as a similar plan was and is at the Sulina mouth of the Danube.

Respectfully yours,

G. W. R. BAYLEY, C. E.

Mr. Bayley's important works are to be found all over the State of Louisiana. His familiarity with and knowledge of the southern part of the Mississippi River, and of the passes into the Gulf, are probably unsurpassed by those of any living engineer. His ability is not questioned, even by the advocates of the canal.

ST. LOUIS, *February* 19, 1874.

Captain James B. Eads:

DEAR SIR—After a careful consideration of the general plans for securing a deep, wide and permanent outlet from the Mississippi River to the Gulf, I beg leave to assure you that I most heartily approve of the plan advocated by you, to confine the river by jetties. I feel satisfied that if the offer made by you to the government be accepted, the object in view will be attained at less cost, and, what is more important still, in a much shorter time than by the construction of a ship canal; and that a wider, deeper, and more constant channel can be obtained by jetties than by dredging.

I see no reason why even the strongest advocate of the construction of a ship canal should object to the acceptance of your proposal by the government, as the surveys and investigations which have to be made before definite plans for a ship canal can be adopted, would leave ample time to carry out your plan far enough to establish its success or failure by results already obtained. If it proves successful, of which I have no doubt, it will save to the government the enormous expense of constructing the

canal, which would, as I firmly believe, largely exceed the estimated amounts. If you should not succeed the government would not have to pay a dollar; and the construction of the canal, provided the plans had meanwhile been carefully prepared, could at once be commenced.

With my best wishes for your success in this important enterprise, I remain, Truly yours,

HENRY FLAD, C E.

In addition to Col. Flad's honorable record as Colonel of the Engineer Regiment of volunteers in the late war, he has had an extensive experience in the construction of important works, involving continual contests with floods and currents. He is president of the Civil Engineers Society of St. Louis, and has been chief assistant engineer of the St. Louis bridge during its construction. His ability as an engineer is recognized among scientific gentlemen both in Europe and America.

Mr. Corthell has recently completed a magnificent bridge across the Mississippi at Louisiana, Mo., and has already won a reputation for professional ability and judgment that would be creditable to a much older engineer. He has had an extensive experience in a class of works calculated to give much value to his views respecting the use and construction of jetties.

COMPARISON OF COST.

The estimated cost of the canal by the United States Board of Engineers exceeds ten millions. In addition to the uncertainty of this amount completing it, there will still be the cost of maintenance when completed. This would probably equal $500,000 per annum. Hence, for the canal and nine years' maintenance the cost would be $15,000,000, or $4,000,000 in excess of the open river mouth; while the value of the latter would be infinitely greater than the canal.

The proposal to build and maintain the jetties for nine years for $11,000,000 is only about one-half of the estimated cost for jetties, including nine years' maintenance of them, as computed by the United States Board of Engineers; and, in addition to this saving, the United States would be certain that they would cost *only* that much, and that they would even then not have to be paid for unless successful.

SOUTH PASS CANAL.

The question of how to open the river to the sea is purely an engineering one, and engineering is founded on *common sense*, quite as much as upon the application of physicial laws and a knowledge of the strength of materials. The people are so deeply interested in the solution of this question, that no plan will be sanctioned by Congress which common sense does not approve. It will never authorize the expenditure of any given sum to make the Fort St. Philip canal, if it be clearly shown that a better one can be made for half the money, no matter how eminent be those that advise it. Common sense will therefore inexorably prevent the building of the Fort St. Philip canal, even if Congress and the new Board of Engineers should decide that a canal is preferable to the jetty system; simply because a much better canal can be constructed in less time and with less money, and of greater capacity.

But little attention had been given to this question by the great majority of engineers, in the army and in civil life, before this controversy arose. Since then, however, it has attracted their attention all over the country, and the facts bearing upon it are to-day so well known, that not a half score of prominent engineers, excepting the few already on record in favor of the Fort St. Philip canal, can be found willing to recommend its construction.

I pointed out to the advocates of the Fort St. Philip canal in Washington the fact that if a canal must be used as an outlet, nature had already furnished one half completed in the South Pass; that this pass was of greater width and depth than their proposed canal; that it simply needed the jetties at its lower end, out across its bar, which their canal needed in Breton Bay; and that two locks could be put at its upper entrance instead of the one their canal would require near Fort St. Philip, thus doubling its capacity; that it would only be necessary to dredge out between the jetties across the bar and at its upper end, instead of the whole length required in the other; and that with it, no unknown, marshy and treacherous territory was to be explored and excavated.

That the South Pass can be converted into a ship canal of double the capacity of the proposed Fort St. Philip canal, and in half the time, and for half the money, will be so evident to any unprejudiced engineer when his attention is directed to it, and is a proposition which appeals so strongly to the common sense of all men,

whether they are engineers or not, that I am justified in asserting that the Fort St. Philip error will never be perpetrated in this generation.

I am emphatically opposed to a canal of any kind in solving this question, because *I know that a deep, open and permanent outlet can be secured without locks.* I urged the submission of all these questions however, to a new board, because I could not learn that the South Pass had ever been suggested by any previous engineer or board, and I felt certain that through a new board the country would either secure an open-mouth river or a canal greatly superior to the Fort St. Philip canal.

The creation of this board was vigorously opposed by the friends of the Fort St. Philip canal scheme, not because it would delay the commencement of their pet project, but because the South Pass canal would be certain death to it, even if the jetty system should not be recommended by the board.

St. Louis, July, 1874.

JAMES B. EADS.